EXECUTIVE SUMMARY

Labor. The simplified TFP method bases the quantity of labor input on the number of employees, reported in the Form M, instead of an index of management and non-management hours worked.

Materials. There is no difference in the way materials input is computed in the original TFP study and the simplified TFP method.

Simplified TFP Method Results

Table E-1 shows the results from the simplified method applied to the nine price cap companies included in our original study--Ameritech, Bell Atlantic, BellSouth, GTE, Nynex, Pacific Telesis, Southern New England, Southwestern Bell, and US West.

Shown in Table E-1 are the annual rates of growth in total output, total input, and TFP. In the original study, average annual TFP growth was found to be 2.4 percent over the 1984-1993 period and 2.8 percent over the 1988-1993 period. Using the simplified method with the nine companies in the original study, average annual TFP growth is 2.9 percent over the 1984-1993 period and 3.0 percent over the 1988-1993 period.

EXECUTIVE SUMMARY

Table E-1
Comparison of LEC TFP Growth for Nine Companies in Original Christensen LEC TFP Study:
Original Results Versus Simplified Method
1984-1993

Year	Total Output Original	Total Output Simplified	Total Input Original	Total Input Simplified	TFP Growth Original	TFP Growth Simplified
1984						
1985	2.4%	2.8%	1.3%	0.6%	1.1%	2.2%
1986	3.0%	3.1%	0.2%	0.8%	2.8%	2.3%
1987	3.7%	3.8%	1.9%	1.1%	1.8%	2.7%
1988	5.2%	5.5%	3.1%	2.0%	2.1%	3.5%
1989	4.8%	4.6%	2.7%	2.8%	2.0%	1.8%
1990	3.7%	4.1%	-0.9%	-0.2%	4.6%	4.3%
1991	2.3%	2.4%	1.1%	0.6%	1.2%	1.8%
1992	1.9%	2.3%	-1.6%	-0.9%	3.5%	3.2%
1993	3.6%	4.2%	1.0%	0.1%	2.6%	4.1%
Average Growth						
1984-93	3.4%.	3.6%	1.0%	0.8%	2.4%	2.9%
1988-93	3.3%	3.5%	0.5%	0.5%	2.8%	3.0%

Table E-2 shows results of the simplified method for 1988 through 1994 with Lincoln and Sprint added to the sample. The starting year for the simplified study with the expanded sample of companies is 1988 rather than 1984. This is done to eliminate adjustments required to 1984-1987 data because of the Uniform System of Accounts Rewrite (USOAR) that took effect in 1988. The expanded sample also contains results for 1994. Using the expanded sample of companies, the simplified method produces average annual TFP growth of 2.9 percent over the 1988-1993 period. Over this

same period, U.S. economy TFP growth averaged 0.1 percent per year, resulting in a TFP growth differential between the LECs and the U.S. economy of 2.8 percent for the 1988-1993 period. For the 1989-1994 period, LEC TFP growth averaged 3.1 percent per year, U.S. TFP growth averaged 0.3 percent per year, resulting in a TFP growth differential of 2.8 percent.

Table E-2
LEC TFP Using the Simplified Method
Results for Expanded Sample of Eleven Price Cap Companies
1988-1994

Year	Total Output Growth	Total Input Growth	TFP Growth
1988			
1989	4.7%	2.9%	1.8%
1990	3.8%	0.0%	3.8%
1991	2.7%	0.7%	2.0%
1992	2.0%	-1.5%	3.5%
1993	4.0%	0.3%	3.7%
1994	3.8%	1.4%	2.4%
Average Growth			
1988-93	3.5%	0.5%	2.9%
1989-94	3.3%	0.2%	3.1%

Summary

In our original TFP study, our goal was to use the most accurate data available on LEC inputs and outputs to measure LEC TFP growth. In this paper, we show that the methods used in our original study provide an accurate measurement of LEC TFP growth since divestiture. We also

discuss how the simplified TFP method maintains accuracy while meeting the concerns raised by the FCC.

The methods we employed in our original LEC TFP study are rigorously developed from economic theory, and they provide economically meaningful measures of total factor productivity growth. These methods have been widely employed by numerous other productivity studies at the firm, industry, and national level. These methods are also very similar to those used by the U.S. Bureau of Labor Statistics (BLS), which has been publishing total factor productivity for the U.S. economy since 1983.

In most instances, the data in our original study were obtained from publicly-available sources. In some instances the data were obtained from internal company records, and in a few cases were derived from proprietary data. Since the FCC has stated a concern that some of the data used in our TFP study are not accessible and verifiable, we have developed a simplified method of TFP measurement based completely on publicly-available data. We believe that the simplified TFP method maintains accuracy as well as a proper balance between precision in measurement and verifiability.

TOTAL FACTOR PRODUCTIVITY METHODS FOR LOCAL EXCHANGE CARRIER PRICE CAP PLANS

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December 18, 1995

In its Fourth Further Notice of Proposed Rulemaking,[1] the FCC has raised a number of questions regarding the appropriate methods for measuring local exchange carrier total factor productivity (LEC TFP). In particular, various questions have been posed by the FCC regarding the TFP study we submitted in May of 1994 and updated in January of 1995.[2] We respond herein to the issues directly relevant to the Christensen TFP methods.

The methods we employed in our original LEC TFP study are the same as those employed by Christensen, Christensen, and Schoech[3] in their pre-divestiture study of the Bell System. They are rigorously developed from economic theory, and they provide economically meaningful measures of total factor productivity growth. These methods have also been widely employed by numerous other productivity studies at the firm, industry, and

[1] Federal Communications Commission, Fourth Further Notice of Proposed Rulemaking, FCC 95-406, September 27, 1995.
[2] Laurits R. Christensen, Philip E. Schoech, and Mark E. Meitzen, "Productivity of the Local Operating Telephone Companies Subject to Price Cap Regulation," Christensen Associates, May 3, 1994, and "Productivity of the Local Operating Telephone Operating Companies Subject to Price Cap Regulation, 1993 Update," Christensen Associates, January 10, 1995. We refer to these collectively as our original study.
[3] Laurits R. Christensen, Dianne C. Christensen, and Philip E. Schoech, "Total Factor Productivity in the Bell System, 1947-1979," Christensen Associates, September 1981.

national level.[4] These methods are also very similar to those used by the U.S. Bureau of Labor Statistics (BLS), which has been publishing total factor productivity for the U.S. economy since 1983. (Appendix 1 lists the similarities in the methods employed by the BLS and the methods we employed in our LEC TFP study.)

In our original TFP study our goal was to use the most accurate data available on LEC inputs and outputs to measure LEC TFP growth. In most instances, the data were obtained from publicly-available sources. In some instances the data were obtained from internal company records, and in a few cases were derived from proprietary data. The FCC has stated a concern that some of the data used in our TFP study are not accessible and verifiable. Because of this concern, we have developed a simplified method of TFP measurement based completely on publicly-available data. In addition this model has simplified some of the computations, while continuing to represent standard practices in TFP measurement. We believe that the simplified TFP method maintains accuracy and addresses concerns about verifiability.

In the remainder of this paper, we respond to questions raised by the FCC. We show that the methods used in our original study provide an accurate measurement of LEC TFP growth since divestiture. We discuss

[4] Our methods and data sources have also gone through a peer review process at the Journal of Regulatory Economics, which has accepted our LEC productivity study for publication.

how the simplified TFP method maintains accuracy while meeting the concerns raised by the FCC. Finally, we summarize the main features of the simplified TFP method and present its results.

Issue 1a. What is the most reasonable method to develop output price indices for TFP calculation purposes? What data source should be used to develop output price indices?

We believe that the methods employed in our original LEC TFP study are the most reasonable methods for developing output price indexes for TFP measurement. These methods provide a proper balance between the demands of economic theory and the constraints of data availability. Furthermore, we believe that the data sources we used in our original TFP study provide the most accurate basis for measuring LEC TFP growth. Most of the data sources are also publicly available. Only two of the data series used in the computation of output growth, billed long distance revenue and billed intrastate access revenue, are not obtained from publicly-available data sources.[5] Since concerns have been raised regarding data not obtained from publicly-available sources, the simplified TFP method that we are now proposing substitutes booked revenue--which is reported in the Form M and the ARMIS 43-02 Report--for billed revenue in the output computation. This modification results in little difference in the TFP results. By basing the

[5] Prior to the reporting of Actual Price Indexes (API's) we relied upon non-public data for the computation of the Special Access price index. However, once API's became available, they were incorporated into the study.

simplified model entirely on publicly-available data, we believe a balance is established between precision and the FCC's stated concerns that all data be accessible and verifiable.

Our computation of LEC output in the original TFP study was based on a two-step approach that is commonly used in productivity analysis. At the first stage, we identified the major categories of output: local service, interstate end-user access, interstate switched access, interstate special access, intrastate access, long distance, and miscellaneous service. Price and quantity indexes were established for each of the service categories. The quantity indexes were then aggregated into a quantity index of total output, using the Tornqvist index. The Tornqvist index is a member of the "superlative index" family, and is a proper basis for computing total output.[6]

The FCC asks whether our categorization of outputs is appropriate, specifically whether there should be more categories, fewer categories, or whether services should be combined differently. The seven service categories identified in our study are a reasonable categorization of LEC services, based on the revenue accounts reported in the Form M/ARMIS 43-02. One cannot construct a more detailed set of service categories or combine services differently with publicly-available data. One can base the

[6] A superlative index number is one that accurately reflects price and quantity changes for a wide variety of production structures. The employment of superlative index numbers guarantees that price changes are accurately captured in productivity analysis, even when the underlying production characteristics of the LECs are not known. For a discussion of superlative index numbers, see W.E. Diewert, "Exact and Superlative Index Numbers," Journal of Econometrics, Vol. 4 (1976), pp. 115-145.

output price computation on fewer categories of output if the underlying price information is maintained in the computation.

The FCC also questions the methods used to construct price indexes for each service category. In particular the FCC questions whether the method used to construct price indexes for local service, intrastate access, and long distance is "ad hoc." The methods chosen for constructing the price indexes were based on the objective of accurately representing price changes for each service category, subject to data availability. The ARMIS 43-02 Report contains the only publicly-available data on price cap LEC rate changes for local, long distance, and intrastate access services. The formula we employed to convert the Form M data into local, long distance, and intrastate access price indexes is an approximation to a chain-weighted Paasche price index (as we show in Appendix 2). The chain-weighted Paasche price index is a conventional price index formula that has a number of attractive properties and is theoretically superior to the traditional fixed-weight Laspeyres and Paasche price indexes.[7]

The price indexes for interstate end-user access, interstate switched access, and interstate special access also conform to the principles underlying the economic theory of price indexes and are based on publicly-

[7] The chain-weighted Paasche price index provides a first-order approximation to superlative index numbers. This implies that the chain-weighted Paasche price index will generally produce results similar to those obtained by a superlative price index. The fixed-weight Paasche and Laspeyres price indexes do not provide a first-order approximation to superlative index numbers. See W.E. Diewert, "Superlative Index Numbers and Consistency in Aggregation," Econometrica, Vol. 46 (1978), pp. 883-900.

available data. The Gross Domestic Product Price Index (GDPPI) is used as a proxy price index for miscellaneous services because of the diversity of miscellaneous services and the lack of data on prices actually paid by customers for miscellaneous LEC services. The GDPPI is based on the Laspeyres price index.

The only reasonable publicly-available alternatives to Form M data for approximating LEC output prices are Producer Price Indexes (PPIs) published by the U.S. Bureau of Labor Statistics.[8] The PPIs suffer from two methodological problems. First, the PPIs cover the entire telephone industry, not just the price cap LECs. This is particularly significant for the toll PPIs. Most LECs only provide intra-LATA toll service, and there is no reason to believe that LEC toll prices mimic toll prices for the rest of the industry. The second problem with the PPIs is that they are based on a fixed basket of services. Since PPIs do not incorporate changes in customer purchases of telephone services over time, they tend to overstate the rate of inflation in telephone rates. Therefore use of the PPIs would result in an understatement in the rate of TFP growth. Table 1 compares output growth from our original TFP study with measured output growth using the PPIs. The table documents the fact that in recent years using the PPIs for

[8]The Bureau of Labor Statistics also publishes Consumer Price Indexes (CPI) for telephone services, but these price indexes are inappropriate for measuring LEC output since the CPI indexes only look at prices paid by residential customers.

telephone service instead of the price indexes developed from Form M data would lead to a lower measured rate of LEC TFP growth.[9]

Table 1
Sensitivity Analysis:
Original Christensen LEC TFP Study Results Versus
Use of Producer Price Indexes to Deflate Local and Long Distance Revenue
1984-1993

Year	TFP Growth Original Study	TFP Growth Using PPIs
1984		
1985	1.1%	0.2%
1986	2.8%	2.5%
1987	1.8%	1.8%
1988	2.1%	2.0%
1989	2.0%	-0.5%
1990	4.6%	3.6%
1991	1.2%	1.1%
1992	3.5%	3.0%
1993	2.6%	2.4%
Average, 1984-93	2.4%	1.7%

Finally, the FCC asks whether basing the total output index on cost elasticity weights would be preferable to basing the total output index on revenue weights. As we demonstrated in our original TFP study, an output index based on revenue weights is the proper specification.[10] It is

[9] Until recently there has been a third problem with the Producer Price Indexes. Until this year, the PPIs were only designed for selected telephone services. In July of 1995, the Bureau of Labor Statistics discontinued the Producer Price Indexes for these selected telephone services and began publication of a set of Producer Price Indexes that provided comprehensive coverage of telecommunications services. The new indexes are not directly comparable to the old series. This lack of comparability is an additional reason that PPIs should not be used to compute output growth. See "New Producer Price Index for the Telecommunications Industry," Producer Price Indexes, U.S. Department of Labor, Bureau of Labor Statistics, July 1995, p.5.

[10] L.R. Christensen, P.E. Schoech, and M.E. Meitzen, Productivity of the Local Operating Telephone Companies Subject to Price Cap Regulation, May 3, 1994, p.iii and Appendix 1.

noteworthy that basing the output index on marginal cost weights instead of revenue weights would reduce the measured rate of total factor productivity growth, since the cost elasticity weights give greater weight to output categories that have experienced lower growth. Crandall and Galst[11] estimate that using a cost-elasticity based output index instead of a revenue based output index reduces the annual rate of telephone industry TFP growth by 1.7 percentage points over the 1981-1988 period. Fuss[12] estimates that using a cost-elasticity based output index instead of a revenue based output index reduces the annual rate of Bell Canada TFP growth by 2.0 percentage points over the 1980-1989 period.

In our original study, the computation of quantity indexes for long distance and intrastate access were obtained by dividing billed revenue by a price index reflecting prices paid by consumers. Billed revenue is not available from publicly-available data sources, however, and therefore the FCC may not feel that the series are adequately accessible and verifiable. In the simplified model, we construct the quantities of long distance and intrastate access services from booked revenue. Booked revenue is published in the ARMIS 43-02 and therefore meets the FCC criteria of accessibility and verifiability. In Table 2 we compare the measured growth

[11] Robert W. Crandall and Jonathan Galst, "Productivity Growth in the U.S. Telecommunications Sector: The Impact of the AT&T Divestiture," The Brookings Institution, February 1991.
[12] Melvyn A. Fuss, "Telecommunications Growth in Canadian Telecommunications," Canadian Journal of Economics, May 1993.

in output when booked revenue is used instead of billed revenue. As one can see from the table, this modification produces similar results.

Table 2
Sensitivity Analysis:
Original Christensen LEC TFP Study Results Versus
Use of Booked Revenue for Long Distance and Intrastate Access
1984-1993

Year	TFP Growth Original Study	TFP Growth Using Booked Revenue
1984		
1985	1.1%	1.5%
1986	2.8%	2.9%
1987	1.8%	1.9%
1988	2.1%	2.4%
1989	2.0%	1.9%
1990	4.6%	5.0%
1991	1.2%	1.3%
1992	3.5%	3.9%
1993	2.6%	3.2%
Average, 1984-93	2.4%	2.6%

Issue 1b. What is the most appropriate measure of the cost of capital for a TFP study?

In our original study, we used the Moody's public utility bond yield as a proxy for the cost of capital. We used the Moody's bond yield because (1) it is publicly available, (2) it is updated annually, and (3) our TFP results were not very sensitive to this choice. The reason that our TFP results were not greatly affected by our choice of the Moody's bond yield is that the cost of capital does not affect the measured quantities of input for different capital asset classes, and only has a slight impact on the weights given the

different capital asset classes in measured total input. Therefore, total input changes by only a slight amount.

The actual cost of capital for Local Exchange Carriers is an average of the cost of debt and the cost of equity. In response to the FCC's questions regarding the appropriate cost of capital, our simplified TFP method employs a proxy for the cost of capital that includes both the cost of debt and the cost of equity. The simplified TFP method uses the cost of capital for the U.S. economy implicit in the U.S. National Income and Product Accounts, as discussed in the Christensen affidavit of February 1, 1995.[13] Because capital markets are national and because the riskiness of telephone assets and other assets in the U.S. economy are similar, year-to-year changes in the telephone industry cost of capital should follow year-to-year changes in the U.S. economy cost of capital. Furthermore, using the cost of capital implicit in the U.S. National Income and Product Accounts would treat LEC and economy-wide capital costs symmetrically. All the data used to compute the U.S. economy cost of capital are produced by the U.S. Bureau of Economic Analysis and are publicly available. Therefore they meet the FCC criteria of accessibility and verifiability.

The data that are used to calculate the U.S. cost of capital are also released annually; therefore the cost of capital can be calculated each year

[13] "An Input Price Adjustment Would be an Inappropriate Addition to the LEC Price Cap Formula: Affidavit of Dr. Laurits R. Christensen on Behalf of the United States Telephone Association," CC Docket No. 94-1, February 1, 1995.

in a straightforward manner. This will allow the cost of capital to be kept current in the rental price equation. Table 3 compares the measured growth in TFP when the U.S. cost of capital is used instead of Moody's bond yield.

Table 3
Sensitivity Analysis:
Original Christensen LEC TFP Study Results Versus
Use of U.S. Cost of Capital for Measuring LEC Cost of Capital
1984-1993

Year	TFP Growth Original Study	TFP Growth Using U.S. Cost of Capital
1984		
1985	1.1%	1.1%
1986	2.8%	2.6%
1987	1.8%	1.6%
1988	2.1%	2.1%
1989	2.0%	1.9%
1990	4.6%	4.3%
1991	1.2%	1.0%
1992	3.5%	3.1%
1993	2.6%	2.4%
Average, 1984-93	2.4%	2.2%

The FCC asks whether the authorized rate of return should be used as the LEC cost of capital. While the FCC's authorized rate of return also includes debt and equity components, it continues the regulatory burden of represcription proceedings. Furthermore, the effort involved in these proceedings is significant enough that they are conducted infrequently, and therefore can lead to relatively large stepwise changes in the authorized rate of return. This in turn would increase the volatility of the implicit rental

prices. These difficulties with the authorized rate of return make it an inferior alternative to the U.S. cost of capital.

To summarize, while Moody's bond yield provides a good proxy to the LEC cost of capital for purposes of measuring LEC TFP growth, it does not incorporate an equity component. To address this concern, our simplified method uses the cost of capital in the U.S. economy as a proxy for the LEC cost of capital. We believe that this represents the best available measure of the cost of capital for the LEC TFP study.

Issue 1c. What are appropriate depreciation rates for a TFP study?

The economic rates of depreciation that we used in our original TFP study are based on extensive academic research. This research has previously been summarized by Hulten and Wykoff [14] and Hulten.[15] This research points to the conclusion that depreciation for classes of assets is geometric, and that this geometric rate of depreciation is tied to the lifetimes of the assets in the class.[16] Hulten and Wykoff developed economic depreciation rates for broad categories of assets, based on expected lifetimes used by the U.S. Bureau of Economic Analysis and the

[14] Charles R. Hulten and Frank C. Wykoff, "The Measurement of Economic Depreciation," in C.R. Hulten, ed., Depreciation, Inflation, and the Taxation of Income from Capital, (Washington DC: Urban Institute, 1981), pp. 81-125.
[15] Charles R. Hulten, "The Measurement of Capital," in E.R. Berndt and J.E. Triplett, eds. Fifty Years of Economic Measurement, (Chicago: University of Chicago Press, 1990), pp. 119-152.
[16] Hulten and Wykoff found that the depreciation rate for equipment equals 1.65/T and the depreciation rate for structures equals .91/T, where T is the expected useful life of a newly-installed asset.

U.S. Bureau of Labor Statistics for purposes of measuring capital in the U.S. economy. Jorgenson updated the Hulten-Wykoff rates for recent changes in the Bureau of Economic Analysis expected lifetimes.[17]

Based on the fact that the rates we used in our original study are consistent with the economic literature on depreciation and because they are based on the lifetimes currently used by the U.S. Bureau of Economic Analysis and U.S. Bureau of Labor Statistics, we believe that they are the most appropriate rates for use in a TFP study. Given that the Bureau of Labor Statistics uses the same lifetimes as those used in our original study, there exists a symmetry between our TFP study and the Bureau of Labor Statistics measure of productivity for the U.S. economy. We therefore employ the same depreciation rates in the simplified TFP method.

The U.S. Bureau of Economic Analysis reviews and adjusts its expected lifetimes approximately every five years, in conjunction with its capital stock benchmark revisions. It would be appropriate to adjust the simplified TFP method depreciation rates whenever the Bureau of Economic Analysis makes substantial revisions to its lifetimes. The new depreciation rates would be derived from the Hulten-Wykoff formulas linking depreciation rates to expected lifetimes.

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[17] Dale W. Jorgenson, "Productivity and Economic Growth," in E.R. Berndt and J.E. Triplett, eds. Fifty Years of Economic Measurement, (Chicago: University of Chicago Press, 1990), pp. 19-118.

The FCC asks whether prescribed depreciation rates should be used in the productivity study. Since prescribed depreciation rates are not based on economic theory or on recent empirical research on economic depreciation, they may differ substantially from economic depreciation. Similarly, the bands established by the FCC for streamlined treatment of depreciation are not based on economic theory or recent empirical research, and therefore the bands may not establish reliable bounds for economic depreciation rates. In conclusion, prescribed depreciation rates should not be used in the productivity study.

The Commission also asks whether the computation of capital input should be based on the thirty capital accounts under Part 32 rules instead of the six accounts in our study. We do not believe that it is possible to obtain all the detailed data needed to construct a capital input measure based on thirty capital accounts. Furthermore, any movement in this direction would be in conflict with the FCC stated goal of simplifying the calculation.

Issue 1d: What is the most reasonable method to estimate capital stock?

In our original TFP study we employed the perpetual inventory method to measure capital stock. The perpetual inventory method is widely used in productivity research, is currently used by the U.S. Bureau of Labor Statistics in all of its total factor productivity studies, and is the most reasonable method for measuring capital stock in a LEC TFP study. In order

to improve upon the perpetual inventory method, one would need to collect information on all LEC plant and equipment, by vintage, for each year of the LEC study.[18] The data requirements for such an approach are prohibitive. Because the perpetual inventory method is the most reasonable approach for measuring capital stock, we use it for purposes of measuring capital stock in the simplified TFP method.

The proper basis for establishing the benchmark or starting value of capital in the perpetual inventory equation is consistency with the depreciation assumptions employed in the study. Both our original study and the simplified TFP method are based on the economic rates of depreciation, which are geometric rates. Therefore the starting value of capital must be consistent with these economic depreciation rates. Furthermore, the benchmark cannot be contaminated by changes in the purchase prices of new assets over time.

In our original study, the LECs were able to provide us with current-cost of gross stock estimates of end-of-year 1984 plant and equipment.[19] This provided us the basis for the benchmark. The current-cost of gross

[18] For a survey of the methods used to construct capital stock indexes, see Dale W. Jorgenson, "Capital as a Factor of Production," in D.W. Jorgenson and R. Landau, eds., Technology and Capital Formation, (Cambridge MA: MIT Press, 1989), pp. 1-35, and Charles R. Hulten, "The Measurement of Capital," in E.R. Berndt and J.E. Triplett, eds. Fifty Years of Economic Measurement, (Chicago:University of Chicago Press, 1990), pp. 119-152.

[19] The current-cost of gross stock was also referred to as the replacement value of the stock.

stock correctly adjusts for changes in the purchase price of new assets over time, but it does not adjust for economic depreciation.

In order to incorporate the effects of depreciation on the benchmark value, the current-cost of gross plant was multiplied by the Economic Stock Adjustment Factor. The Economic Stock Adjustment Factor represents the ratio of the stock's economic value to the current cost of gross stock. Conceptually, there is no "choice" regarding the basis for Economic Stock Adjustment Factor; the only appropriate factor is the ratio of the economic value of capital stock to gross stock in current dollars. In order to measure this ratio, one needs information on the age distribution of assets in the telephone industry. We used best publicly-available information on the age distribution of telephone industry assets -- that collected by the Bureau of Economic Analysis for purposes of constructing capital stock estimates for the telephone and telegraph industry.

Because the company's 1984 current cost of gross stock is not obtained from a publicly-available data source, it may not meet the FCC's accessibility and verifiability criteria. For that reason, the benchmarks in the simplified TFP method are based on the original cost (book value) of gross stock, reported in the Form M.[20] The book value of gross stock does not

[20] The benchmark is also established for beginning-of-year 1988, using the Part 32 accounting categories. Moving the benchmark to 1988 and basing it on Part 32 accounts simplifies the computational procedures. One must recognize, however, that the beginning-of-year 1988 plant and equipment reported using Part 32 still contains assets that are expensed rather than capitalized in later years. Therefore one must take this into account when establishing the benchmark.

adjust for either economic depreciation or changes in the purchase prices of new assets over time. Therefore the book value of gross stock needs to be multiplied by its own Economic Stock Adjustment factor, one that incorporates both depreciation and changes in the purchase prices of new assets. This adjustment factor is the ratio of the economic value of the stock to the book value of gross stock. To avoid confusion with the Economic Stock Adjustment factor used in the original study, we refer to the adjustment factor in the simplified TFP method as the Economic Value/Book Value Adjustment Factor.

Neither the book value of gross plant nor the book value of net plant can be used as benchmark values in the perpetual inventory equation unless they are adjusted for economic depreciation and inflation in the purchase prices of new assets. Either can be used if it is correctly adjusted; furthermore the correctly adjusted book values of gross and net plant will produce the same benchmark. Table 4 shows the impact on measured TFP growth of using the beginning-of-year 1988 book value of stock to estimate capital benchmarks.

Table 4
Sensitivity Analysis:
Original Christensen LEC TFP Study Results Versus Use of 1988 B-O-Y Book Value of Gross Stock to Estimate Capital Benchmarks, 1984-1993

Year	TFP Growth Original Study	TFP Growth Using 1988 Book Value of Stock
1984		
1985	1.1%	1.4%
1986	2.8%	3.0%
1987	1.8%	2.0%
1988	2.1%	2.3%
1989	2.0%	2.1%
1990	4.6%	4.7%
1991	1.2%	1.3%
1992	3.5%	3.6%
1993	2.6%	2.7%
Average, 1984-93	2.4%	2.6%

In order to apply the perpetual inventory equation, book value of investment must be converted to the quantity of investment. This is achieved by dividing the book value of investment by a price index representing the prices paid for plant and equipment. In our original study this was done by dividing book value by Telephone Plant Indexes (TPIs) provided by the LECs. We used the TPIs in our original study because we believed that they provided the best information on prices actually paid by LECs for plant and equipment.

The TPIs are based on proprietary data and therefore are not readily accessible and verifiable. Because of the FCC's stated concerns regarding accessibility and verifiability, the simplified TFP method does not rely on the

TPIs. Instead the quantities of investment are calculated by using U.S. Bureau of Economic Analysis (BEA) price indexes for nonresidential structures and producer durable equipment. While BEA price indexes are not based on the prices actually paid by LECs for plant and equipment, they provide a reasonable approximation to them.

The simplified TFP method uses the BEA telephone structures price index for buildings and cable and wire. For central office switching equipment, transmission equipment, and information origination/termination equipment, the simplified TFP method uses the BEA producer durable equipment price index for communications equipment. For general support equipment, the simplified TFP method uses a Tornqvist index of four BEA producer durable equipment price indexes: office, computing, and accounting machinery; furniture and fixtures; trucks, buses, and truck trailers; and non-residential producer durable equipment. The weights used in the Tornqvist index are based on the book value of gross additions in general purpose computers, furniture and office equipment, motor vehicles, and other general support equipment. Table 5 shows the impact on measured TFP growth of using BEA price indexes to obtain investment quantities.

Table 5
Sensitivity Analysis:
Original Christensen LEC TFP Study Results Versus
Use of BEA Price Indexes to Obtain Quantity of Investment
1984-1993

Year	TFP Growth Original Study	TFP Growth Using BEA Price Indexes
1984		
1985	1.1%	0.9%
1986	2.8%	2.8%
1987	1.8%	1.8%
1988	2.1%	2.1%
1989	2.0%	2.0%
1990	4.6%	4.8%
1991	1.2%	1.3%
1992	3.5%	3.6%
1993	2.6%	2.8%
Average, 1984-93	2.4%	2.5%

To summarize, the method and data sources employed in our original study provided an accurate measure of LEC capital stock. Because of the FCC's stated concerns regarding the accessibility and verifiability of all data used to construct capital stocks, we have proposed a simplified method for computing capital stock that is based entirely on publicly-available data using the same method for measuring capital stock as our original study.

Issue 1e: Is the imputation of capital services from capital stock rather than from capital consumption reasonable?

Capital stock is the most reasonable basis for measuring the quantity of capital input, and in fact it is the standard approach in productivity

research. For example, the Bureau of Labor Statistics uses capital stock to impute capital services in all total factor productivity studies.[21] The reason that capital stock accurately represents the quantity of capital input is that it weights each vintage of plant and equipment by its relative production efficiency. This means that the stock represents the total amount of capital services that are available for production.

The FCC has defined capital consumption as "the loss of capital efficiency over time." There is no reasonable basis to believe that capital services provided in any year equals the amount by which an asset has lost efficiency. For example, a light bulb maintains a high level of efficiency over a number of years, while providing a high level of service during that time. Yet using capital consumption to measure capital services would incorrectly imply that the light bulb has provided little service.

Both our original TFP study and the simplified TFP method use the quantity of capital stock to measure the quantity of capital input for each asset class. This is the accepted standard in productivity research.

Issue 1f. What is the most reasonable method for developing an implicit rental price?

The implicit rental price formula employed in both the simplified study and our original TFP study is rigorously developed from the economic theory

[21] See U.S. Department of Labor, Bureau of Labor Statistics, Trends in Multifactor Productivity, 1948-81, Bulletin 2178, September 1983, pp. 39-58.